2003 Abe Silverstein Medal Recipient

Rafat R. Ansari

Dr. Rafat R. Ansari is internationally recognized for developing a novel, patented fiber-optic probe for measuring nanometer-size particles suspended in liquids using dynamic light scattering (DLS). He has successfully applied this to a noninvasive technique detecting cataracts and other diseases of the eye at a much earlier stage than possible by any current clinical or laboratory techniques. This probe can detect physiologic change at the molecular level long before any clinical symptoms appear. This feature makes the probe especially attractive for scientists developing drugs to treat or reverse cataracts because they can quantify the efficacy of drug before clinical symptoms appear.

Dr. Ansari's probe is currently being used at the National Eye Institute of the National Institutes of Health (NIH) for clinical trials on human subjects. Tests on dozens of patients have proven the utility of the probe in a clinical setting and NIH personnel are quite pleased with the results. The Food and Drug Administration (FDA) is using the probe in animal model (sand rat) studies to detect the effects of diabetes. Results at FDA have demonstrated that the technique is a practical, sensitive, noninvasive diagnostic tool useful for the early detection of ocular pathologies and understanding the mechanisms of cataracts formation associated with diabetes.

EyeWorld (an international magazine for eye clinicians) selected this probe as one of four new technologies that may significantly impact ophthalmology in the new millennium. In May 2002, Review of Refractive Surgery published a feature article on this probe and stated that this is the only probe that is capable of evaluating the outcome of photorefractive surgery. Medical Design News published a cover story on this probe and touted its many unique capabilities in its May/June 2001 issue.

On February 26, 2003, NASA Administrator Sean O'Keefe in his speech used Dr. Ansari's invention as an "example of how we are using human spaceflight research to do exactly what NASA's vision compels us to do—improve life here."

Having demonstrated its success in clinical and laboratory settings, Dr. Ansari expanded the capabilities and scope of this device to application in total health diagnostics using the eye as a "window to the body." This technology is now being aimed at monitoring astronaut health in space where doctors on ground can monitor astronaut health using this helmet-mounted device with the World Wide Web to make remote health diagnostics a reality. He has started the development of a head-mounted google-like device that can monitor the eye, skin, and brain health of astronauts while in space. This remote health diagnostic device can also be used to provide health care on Earth in areas of the world where clinical facilities are not available.

This state-of-the-art device is finding new applications that include noninvasive detection of diabetic retinopathy, glaucoma, age-related macular degeneration (AMD), LASIK surgery outcomes, Alzheimer's disease, and blood glucose monitoring. Astronauts in space are exposed to a high level of cosmic radiation that has been shown to lead to early occurrence of cataracts. This probe is now being used to study the effect of radiation on mice in labs and to test the efficacy of drugs in reversing or mitigating the effects of radiation and potentially making space exploration safer for humans. Oakland University, Rochester, Michigan, is currently using Dr. Ansari's probe for detecting radiation-induced cataracts and testing drugs to mitigate the effects of radiation on rats.

Dr. Jerry Sebag of Doheny Eye Institute, Keck School of Medicine, University of Southern California, is using Dr. Ansari's device for studying diseases of the vitreous. According to Dr. Sebag, "By not employing any extraneous substances, this noninvasive technique avoids introducing any artifact, making it useful for laboratory investigation of vitreous structure and physiology. Furthermore, the noninvasive nature and low energy level of this laser-based methodology make it potentially very useful for clinical applications. Indeed, it may soon be feasible to improve the ability to evaluate vitreous clinically, for example, by quantitating the degree of liquefaction or presence of a posterior vitreous detachment with greater precision and reproducibility."

Dr. Ansari's outstanding technical contributions have found many applications in biomedical engineering and medical technology.

2004 Abe Silverstein Medal Recipient

Steven M. Arnold

Dr. Arnold's contributions have been substantial and numerous. He has not only shown exceptional talent in his ability to personally perform world-class research in the areas of constitutive modeling (deformation and damage) of materials, structural mechanics, and composite mechanics, but he has also shown excellent technical management skills. Dr. Arnold has been solely responsible for orchestrating, leading, and focusing a unique team of analytical and experimental specialists from the Life Prediction Branch, academia, and industry to develop, experimentally validate, and commercialize robust deformation and life analysis capabilities for both monolithic and composite materials. Here the focus will be only on his contributions in the area of composite mechanics, since this is where his ability to see the forest as well as the trees, his teaming approach, desire for actual tool development (not just papers), and technology transfer have truly stood out the most. For the past 12 years he has spearheaded an effort to build a versatile and user-friendly software package which drives several powerful micromechanics and mesomechanics theories for advanced composites, smart materials, and laminates. Additionally, Dr. Arnold has personally developed deformation and failure models that have been implemented into the award-winning micromechanics analysis code based on the method of cells known as MAC/GMC.

Based on the properties and arrangement of the composite constituents, MAC/GMC predicts the coupled thermo-electro-magneto-elasto-viscoplastic response of arbitrary doubly periodic (continuous) and triply periodic (discontinuous) composites and laminates subjected to general time-dependent loading histories. Damage and failure theories are implemented on several scales such that global composite or laminate life can be predicted from an accumulation of microdamage or microfailure events. The unique combination of capabilities embodied by the MAC/GMC software enables the design and analysis of smart and traditional composite materials for a wide range of structural and multifunctional aerospace applications. Further, this unique package has been used by industry, academia, and government alike (46 customers to date) and placed second in the 1997 NASA Software of the Year competition.

The MAC/GMC software package is scientifically and technologically important as it provides the composite/engineering community with a unique, computationally efficient micromechanics analysis tool that admits physically-based viscoplastic deformation and life models, can analyze multiphased materials, and can assist both the material scientist and structural analyst in developing and utilizing these materials. MAC/GMC's most outstanding features are its (1) ability to accurately model various laminated and woven fiber architectures (including both shape and packing arrangements), (2) interactive multiscale analysis capability—it can predict global failure based on local events with commensurate redistribution of stresses, (3) new smart material capability—fully coupled anisotropic thermomechanical-electromagnetic interaction on all scales: constituents, composites, and laminates, (4) new, more accurate micromechanics model, (5) new constitutive models (e.g., classical plasticity, implicit multimechanism viscoplasticity), and (6) multiscale variable-fidelity yield and failure surfaces for composites and laminates, all accessible at minimal expense both from a computational and required user input standpoint. Also, full multiaxial states of stress or strain may be applied and predicted accurately, regardless of the orientation of the fibers, whereas other approaches in the literature are restricted to predicting primarily longitudinal responses.

Numerous advantages can be stated regarding the MAC/GMC macroconstitutive and microconstitutive laws as compared to the other numerical micromechanical approaches in the literature, such as the finite element unit cell approach. One advantage is that any type of simple or combined loading (multiaxial state of stress) can be applied irrespective of whether symmetry exists or not without resorting to different boundary condition application strategies, as in the case of the finite element unit cell procedure. Another advantage concerns the availability of an analytical expression representing the macro thermo-elasto-magneto-inelastic constitutive law thus ensuring a reduction in memory requirements when implementing this formulation into a structural finite element analysis code. In addition, this formulation has been shown to predict accurate macro behavior given only relatively few subcells, within the repeating cell. If one employs the finite element unit cell procedure, a significant number of finite elements are required within a given repeating unit cell to obtain the same level of accuracy as with the present formulation. Consequently, it is possible to utilize this formulation to efficiently analyze composite structures subjected to complex load histories. This is particularly advantageous when analyzing realistic structural components, given that different loading conditions exist throughout the structure, which in turn necessitates the repeated application of the micromechanical equations at each of these locations.

The impact and significance of MAC/GMC has been felt since its inception. For instance, 17 universities and 29 industrial companies have signed software use agreements for the previous versions of MAC/GMC since 1995. MAC/GMC has been used on a number of previous NASA programs—MMC Life Prediction Cooperative and Third-Generation Reusable Launch Vehicle for example—and currently is a key analysis capability in the morphing structures and smart materials supertasks within the Revolutionary Aeropropulsion Concepts (RAC) Project. MAC/GMC is also serving a variety of other academic and secondary industrial customers. The Goodyear Tire & Rubber Company is one of these secondary customers that has benefited greatly by the development and use of MAC/GMC, as MAC has uniquely enabled them to study and understand the influence of cord architecture on the behavior and performance of their tires (this has resulted in three U.S. patents for a revolutionary tire design). In the academic arena, the role of MAC/GMC is being employed in a number of unique applications. Oregon Health & Science University is using MAC to investigate ways to improve dental composites for improving life of fillings in teeth. The Pennsylvania State University is using MAC/GMC to investigate deformation and damage response issues pertaining to the application of multiaxial states of stress (e.g., determination of flow surfaces) in both continuous and discontinuous reinforced metallic materials. The Ohio State University employs MAC/GMC in the area of nondestructive evaluation. The University of Virginia has used GMC to assist (1) in the hierarchical sensitivity analysis of postbuckling response of composite structures, (2) in the development and analysis of composite material processing techniques, (3) in the analysis of woven composites, and (4) in its automobile safety laboratory to determine the properties of the neural tissue matrix of the brain. These and other universities are using MAC/GMC as a teaching aid as well as a predictive tool. Clearly, MAC/GMC can be classified as a dual-use technology and is being offered to the nonaerospace sector through normal channels. Finally, as a testament to MAC/GMC's impact, a small business, Collier Research and Development Corporation, has been working closely with NASA and the Ohio Aerospace Institute to incorporate this technology into their award-winning commercial product called HyperSizer.

2005 Abe Silverstein Medal Recipient

Mary Ann Meador

For successful development of a series of rod-coil block copolymers that produce easy-to-fabricate, dimensionally stable films for use as ion conducting membranes

Improvements in battery performance characteristics are required to meet future aerospace application requirements—for example, planetary orbiters, landers, and rovers; geosynchronous orbiting and low-Earth orbiting spacecraft; astronaut equipment; reusable launch vehicles; automotive and personal electronic devices—that span a wide variety of operational regimes. Today, various alkaline-based technologies are being used. Existing lithium batteries have historically used a liquid electrolyte to carry ions from anode to cathode, completing the circuit to deliver current. A separator is used to keep the anode from touching the cathode; otherwise the battery would short out, stop functioning, and could become a safety problem. The liquid electrolyte is flammable and incompatible with lithium metal. In addition, both liquid electrolytes and polymer membranes are costly.

Dr. Mary Ann Meador has identified and has very successfully developed a series of rod-coil block copolymers that produce easy-to-fabricate, dimensionally stable films for use as ion-conducting membranes. The polymers consist of short rigid rod segments alternating with flexible coil segments. The highly incompatible rods and coils phase separate to produce nanoscale channels. The coil phase allows for conduction of ions, while the rigid rod phase provides mechanical support. Suitable functionality introduced into the rods or coils produce membranes that can conduct lithium ions for lithium polymer batteries or protons for use in fuel cells. Lithium-based batteries utilizing a solid polymer electrolyte offer significant performance advantages and cost benefits over conventional technologies, including a factor of 2 reduction in mass, a factor of 4 reduction in volume of the energy storage system, and enhanced system reliability and flexibility with lower life-cycle costs.

Development of a solid polymer electrolyte with suitable performance characteristics is an enabling technology. The availability of a solid polymer electrolyte would eliminate solvent from the battery and serve as the anode-cathode separator. The currently available polymer electrolytes have failed to provide suitable ionic conductivity in combination with physical strength and toughness. However, the rod-coil polymers do possess suitable lithium ion conductivity through the coil portion. They can also perform the role of the separator since the rod portion makes the film mechanically strong enough to physically keep the anode and cathode from touching.

Advanced lithium-based polymer batteries can offer (1) higher cell voltage, which allows fewer cells, thus reducing system complexity and manufacturing and assembly costs, (2) higher specific energy and energy density, which improves the efficiency of energy use and storage or enables missions that have critical weight and/or volume margins, (3) construction of environmentally safe materials that operate more safely because there are no free liquids in the battery, (4) greater coulombic and energy efficiencies, (5) operation at over a wide range of temperatures, simplifying thermal system design and expanding the operational envelope and (6) ability to be made much smaller, less expensive, and longer lasting for high-drain consumer electronic devices.

Eveready Battery Company, Inc., manufactures the world's only AA 1.5-V lithium battery, a direct replacement for the traditional alkaline battery with tremendous performance advantages, but it costs considerably more than alkaline batteries, limiting market penetration, and contains a liquid electrolyte and a separator, which makes manufacturing somewhat more costly. Eveready is now working in partnership with NASA Glenn Research Center to replace the current electrolyte-separator combination with the rod-coil polymers capable of fulfilling both functions. The simplified design of the rod-coil polymer-based battery should lower manufacturing costs and increase battery safety. Ferro Corporation is also partnering with NASA Glenn to develop manufacturing capabilities for commercially producing the rod-coil polymers. Hybrid electric vehicles require much larger and thinner polymer films for evaluation. InvenTek Corporation and Lithium Technology Corporation, who develop batteries for hybrid electric vehicles, have expressed interest in testing the rod-coil polymers once samples of sufficient size are available. Rod-coil polymers are also being evaluated as an electrolyte for batteries for future Mars missions under the externally led Code T proposal entitled "Advanced Batteries for Space" with T/J Technologies, Inc., the Jet Propulsion Laboratory, and Lithium Technologies Corporation. The batteries will be easily scalable in size and capacity for applications such as powering manned surface vehicles, unmanned rovers, and spacesuits. For these applications, incorporation of ionic liquids and other additives into the polymer is needed to expand the technology to the low-temperature (–40 °C) regime. Daychem Laboratories, Inc., and The Dow Chemical Company are interested in pursuing a license and collaborating with NASA to further develop the rod-coil polyimides for commercializing batteries.

Dr. Meador's research success and her emphasis on working collaboratively with industry to commercialize the technology has been outstanding. The work has been patented and has received a 2004 Space Act Award, and her journal publication (see Chem. Mater. 2003, 15, 3018–3025) describing the research success was awarded the Glenn Distinguished Publication Award in 2003.